

Case Study: Mid-Atlantic Ozone and PM_{2.5} Episode June 26-30, 2001

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Overview

- Introduction
- Episode Background
- June 26: Explosive Rise in O_3
- June 27: O_3 Remained High,
 $PM_{2.5}$ Remained Moderate
- June 28: $PM_{2.5}$ Concentrations Finally Rose
- June 29: $PM_{2.5}$ Increased Another Notch
- June 30: Slow Termination of Episode

Introduction

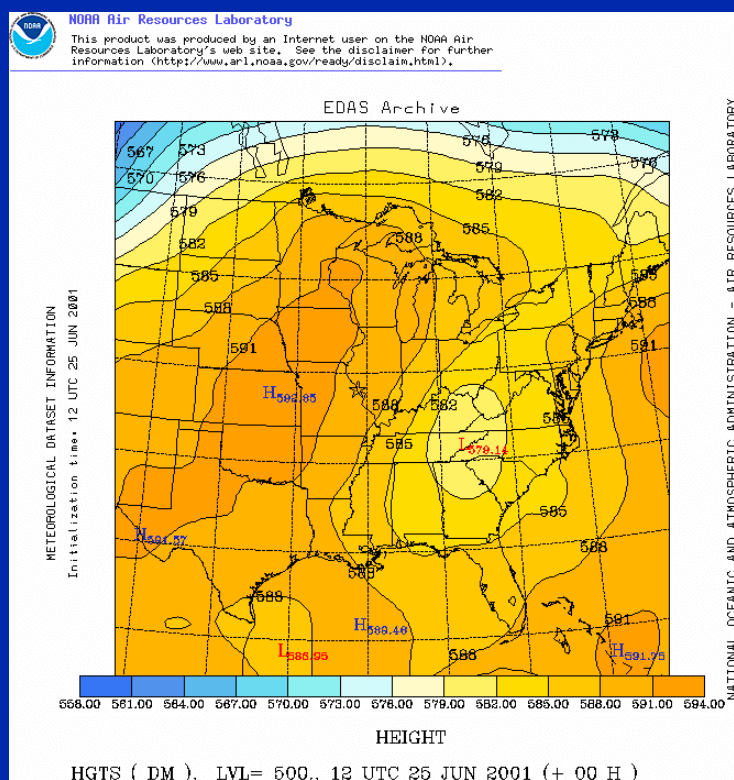
- The mid-Atlantic pollution episode of June 26-30, 2001, was long-lived and featured a rapid onset of high O_3 followed by increasing $PM_{2.5}$ 48 hours later.
- The forecast challenge was to determine why the pollutants did not increase in phase. In this case, O_3 and $PM_{2.5}$ responded differently to changes in air-mass characteristics.

Episode Background

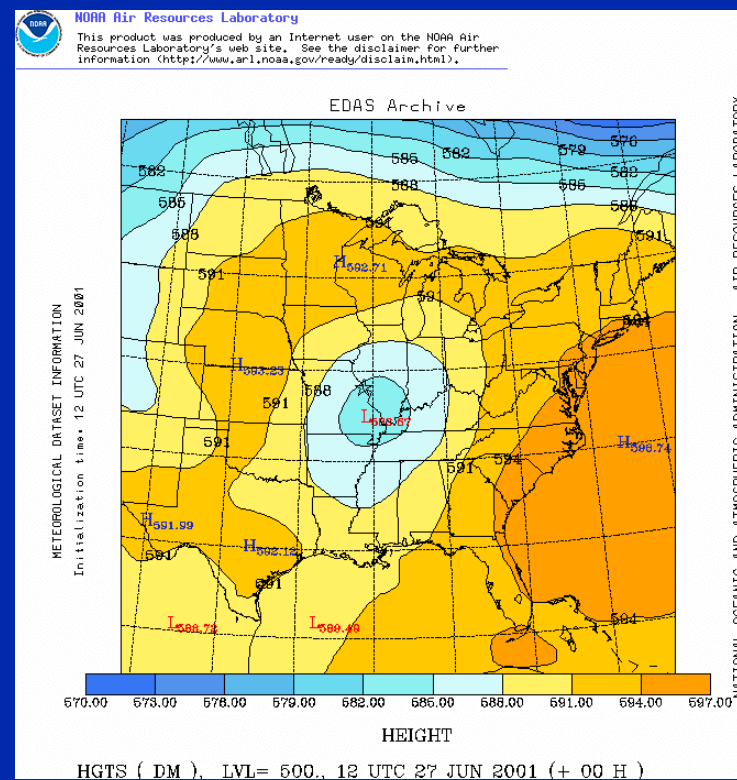
- The larger-scale weather pattern at the onset of the episode was a bit unusual.
 - The “cut-off” upper-level low was trapped beneath a large continental ridge.
- Near the surface, conditions developed in a more standard fashion.
 - High pressure over the Midwest drifted east and linked up with the semi-permanent Bermuda High.

Episode Background – Upper-Air

An upper-level low, cut off from the main westerlies, drifted west from North Carolina to Missouri beneath a strong ridge



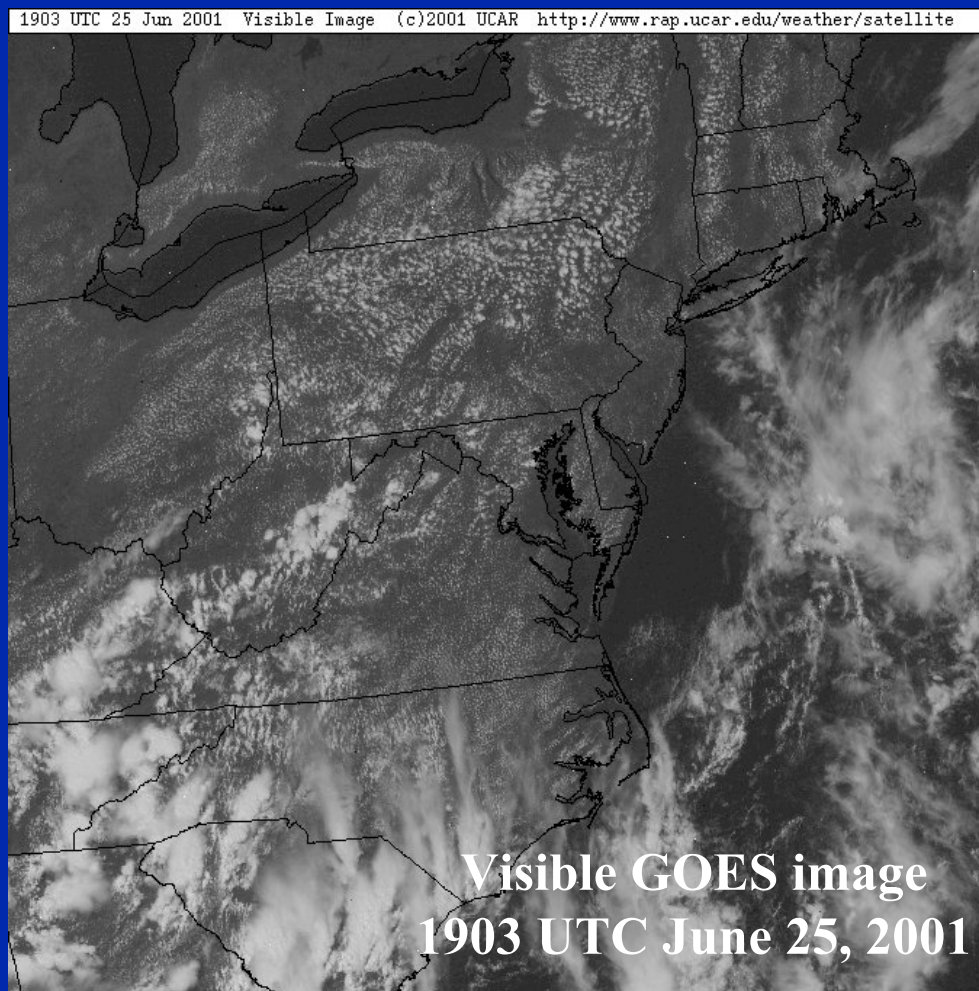
**500-mb Geopotential Height
June 25, 1200 UTC**



**500-mb Geopotential Height
June 27, 1200 UTC**

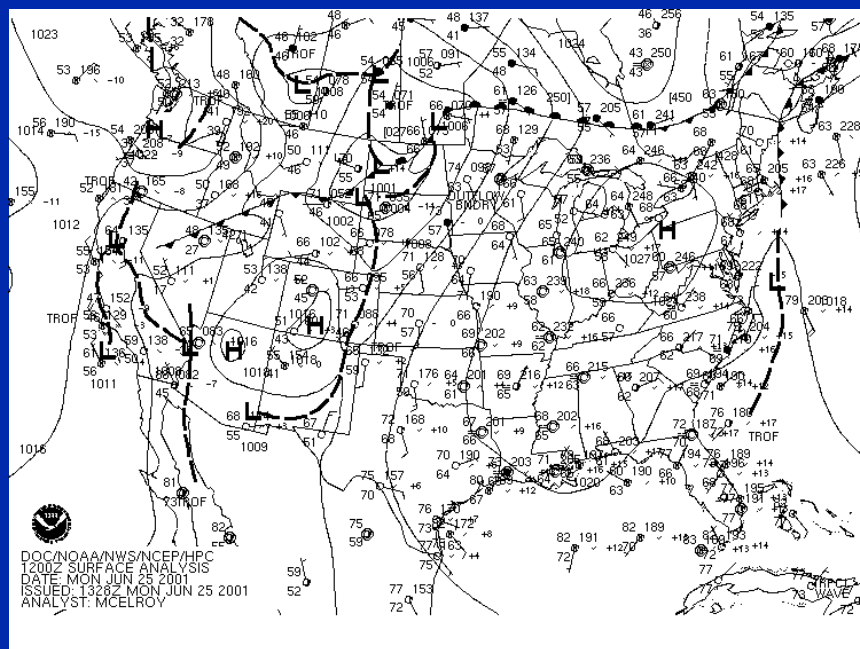
Episode Background – Clouds and Transport

The upper-air low induced convection and suppressed west-to-east transport in the Ohio River Valley – the usual source region for O_3 transported to the mid-Atlantic.

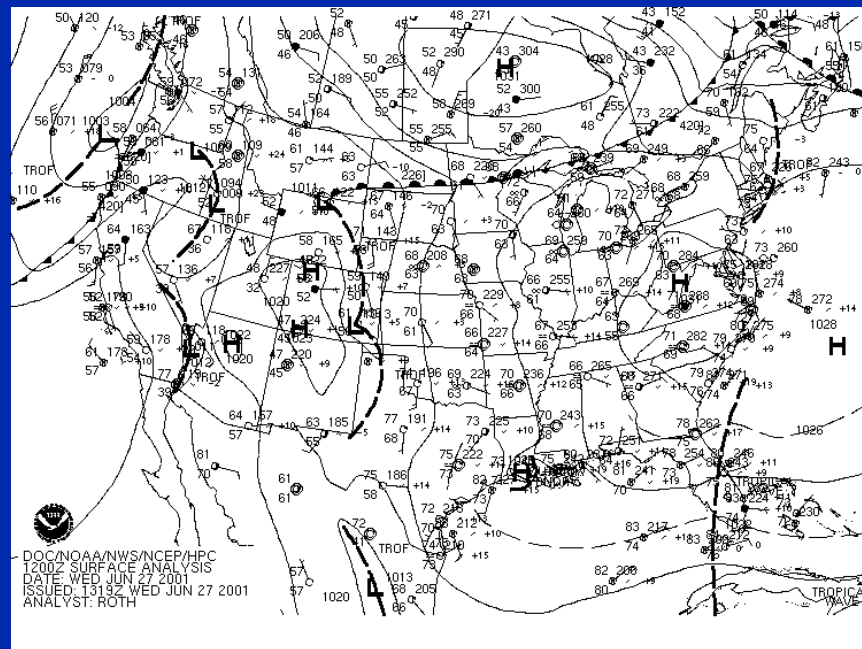


Episode Background – Surface

High pressure moved from the upper Midwest to the mid-Atlantic and linked up with the Bermuda High – a standard high O₃ scenario for the mid-Atlantic.



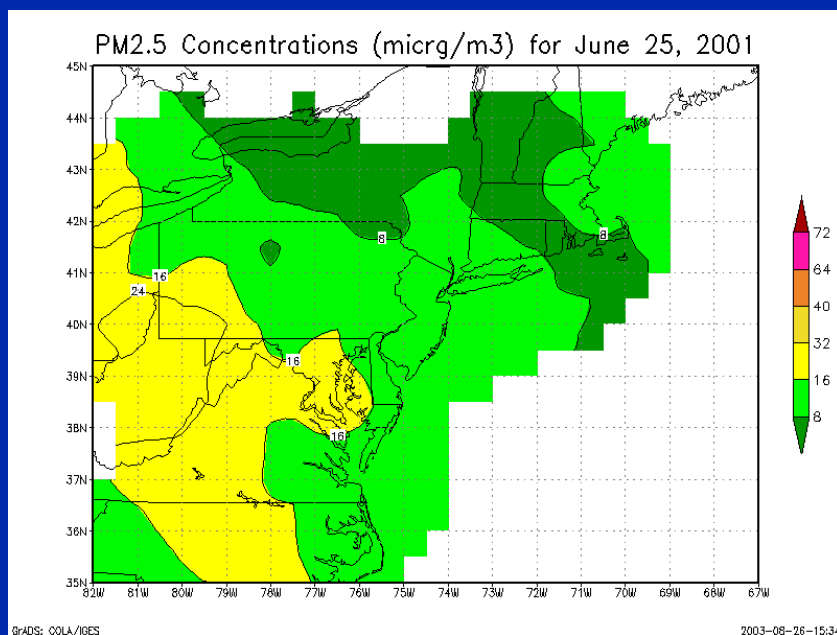
Surface Analysis
June 25, 2001, 1200 UTC



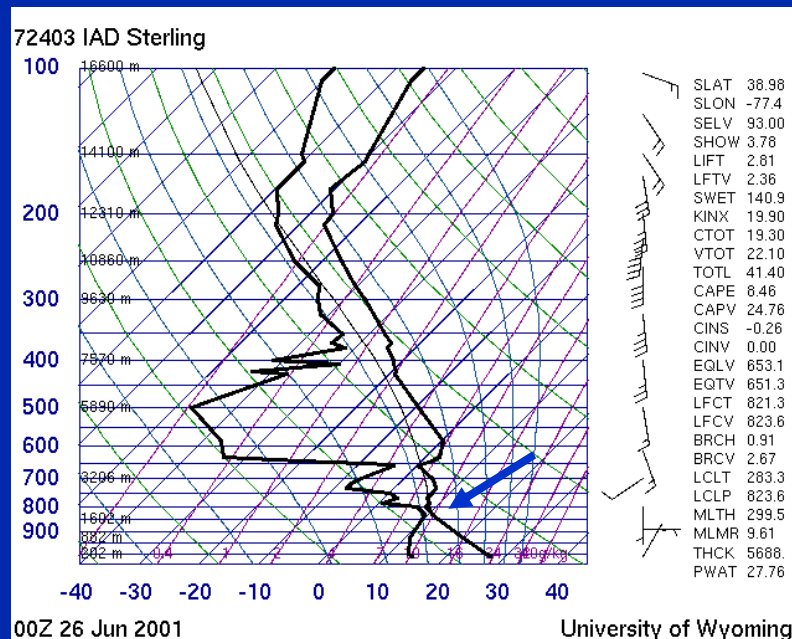
Surface Analysis
June 27, 2001, 1200 UTC

July 25: Day Prior to Episode Onset

O₃ was in the upper-Moderate AQI range with PM_{2.5} (left panel) mainly in the Good range – a pleasant day with temperatures in the mid-80s F, low dew points (50s F), and a deep mixed layer (right panel).



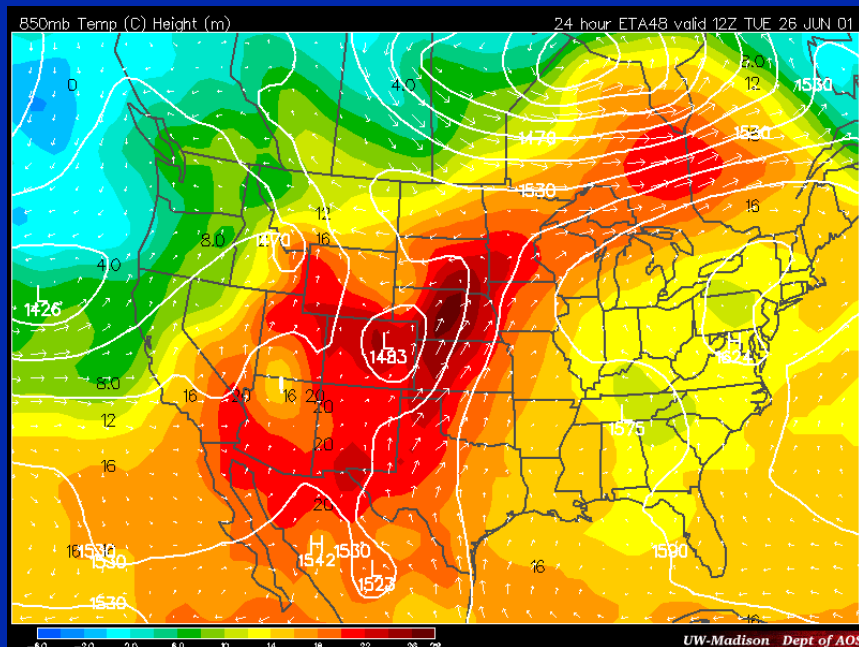
**PM_{2.5} concentrations
June 25, 2001**



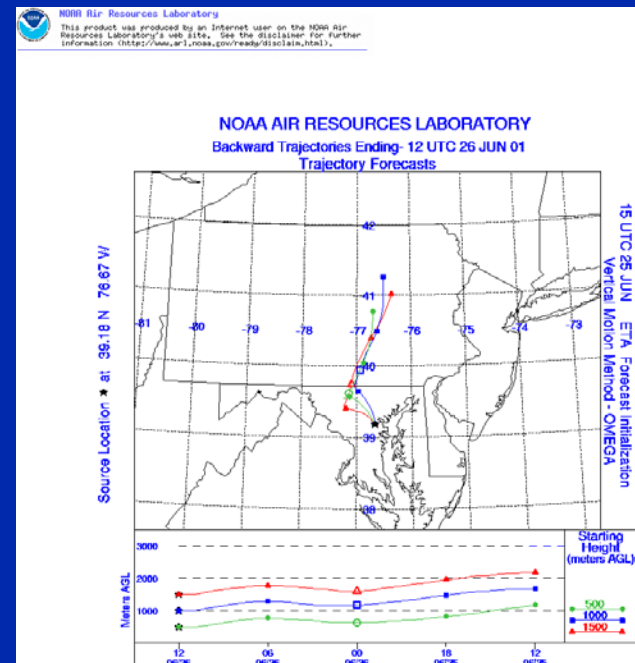
**IAD radiosonde
0000 UTC June 26, 2001**

July 26: Onset of O₃ Episode (1 of 2)

Forecast called for light northerly flow with moderate temperatures. Regional O₃ concentrations were low and Code Orange was forecast.



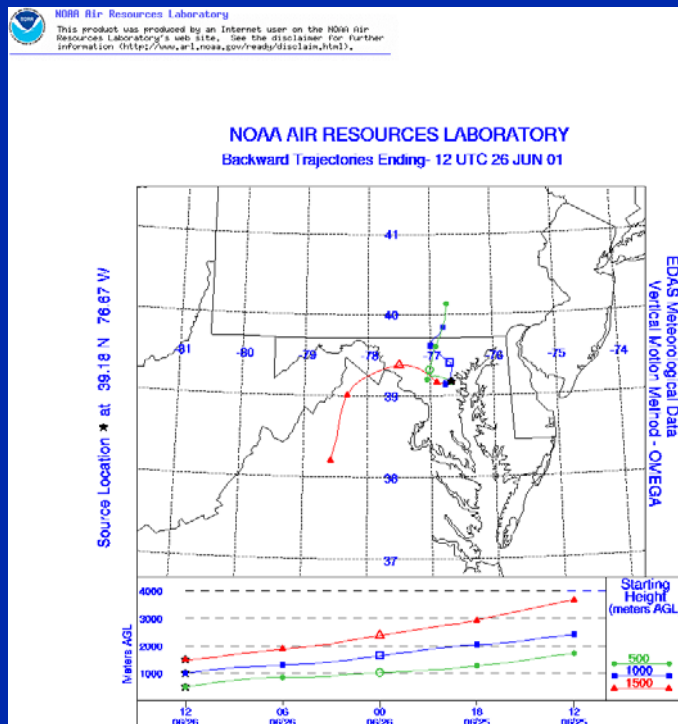
**850-mb Eta Forecast Heights and Temperatures
Valid 1200 UTC June 26, 2001**



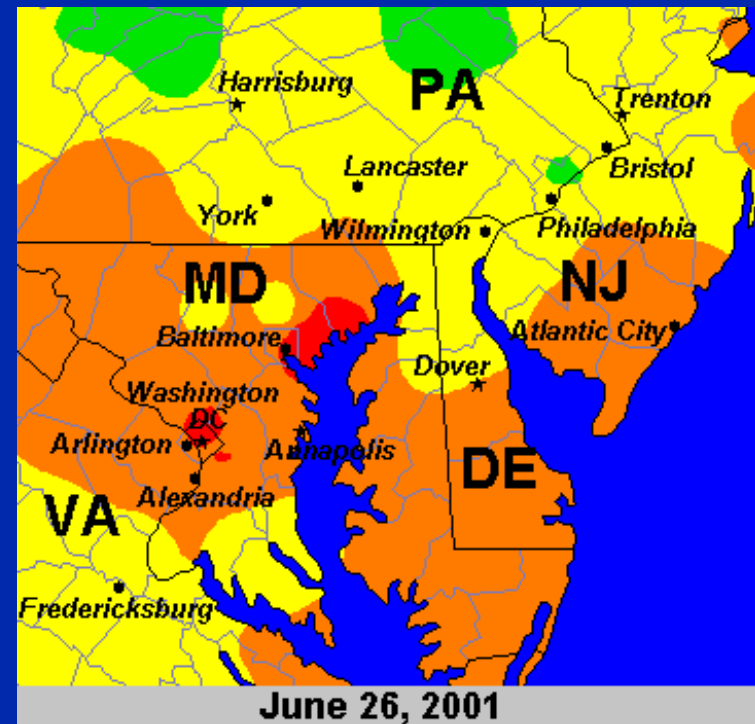
**HYSPLIT forecast trajectory
Valid 1200 UTC June 26, 2001**

June 26: Onset of O₃ Episode (2 of 2)

Stagnation was more intense than forecast, highest O₃ was centered right along the urban I-95 Corridor. PM_{2.5} concentrations remained moderate.



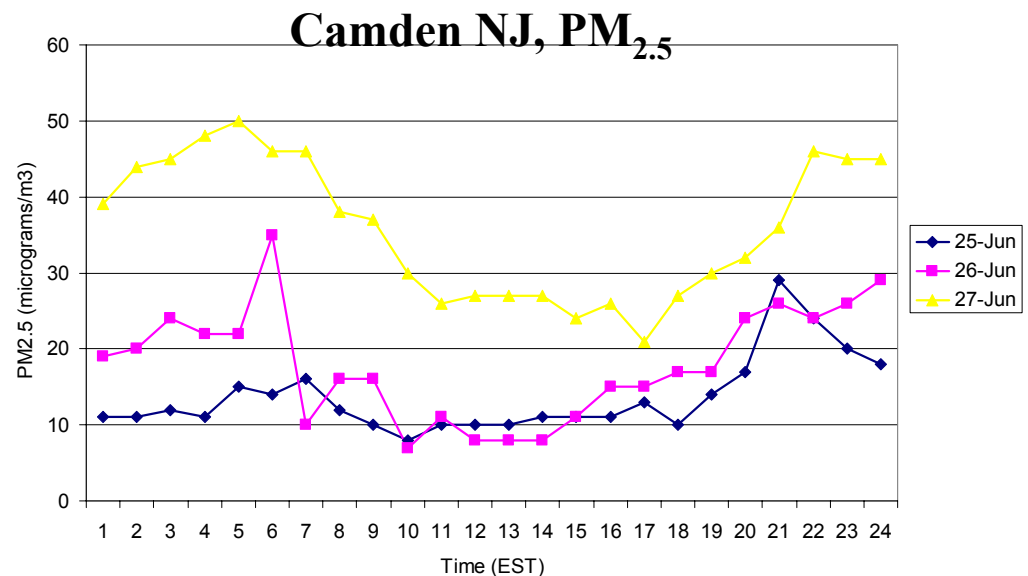
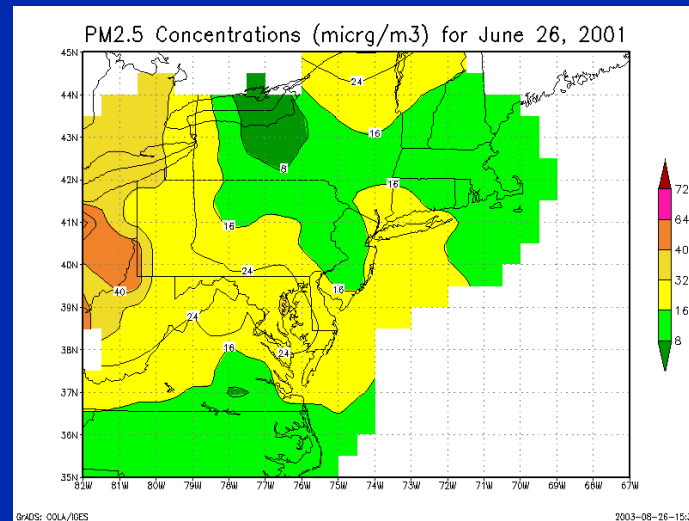
**Analysis back trajectory
June 26, 2001, 1200 UTC**



**Peak 8-hr O₃
AQI color codes**

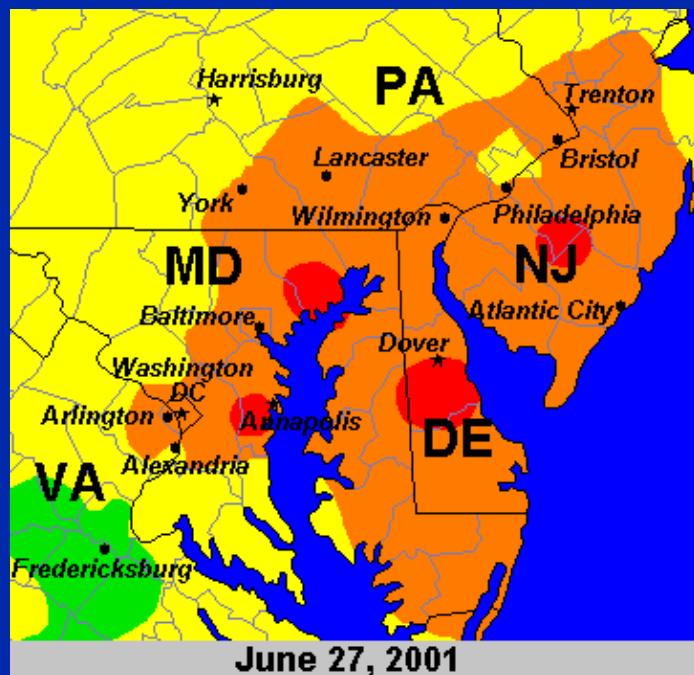
June 26: Why Was $PM_{2.5}$ Moderate?

- Air mass remained dry until late on June 26.
- The regional load of $PM_{2.5}$ was low. As the boundary layer mixed upward in the afternoon, cleaner air was entrained and concentrations fell (bottom panel).

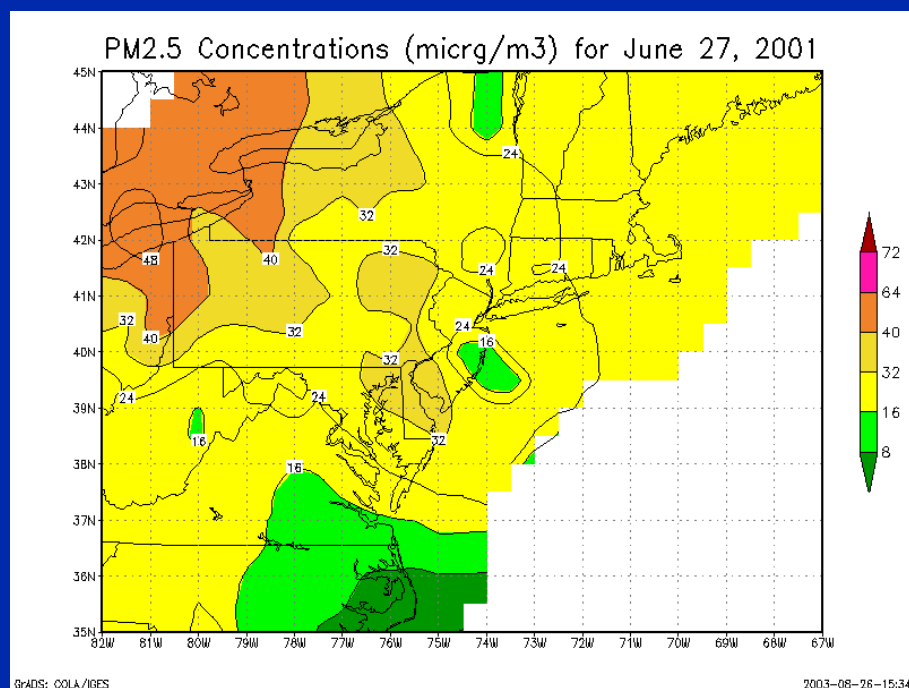


June 27: Code Red O_3 , $PM_{2.5}$ Still Moderate (1 of 2)

$PM_{2.5}$ concentrations began to rise but remained in the Moderate range. Code Orange $PM_{2.5}$ concentrations were found northwest of the mid-Atlantic. Peak O_3 concentrations were now found in the usual locations downwind of the urban cores.



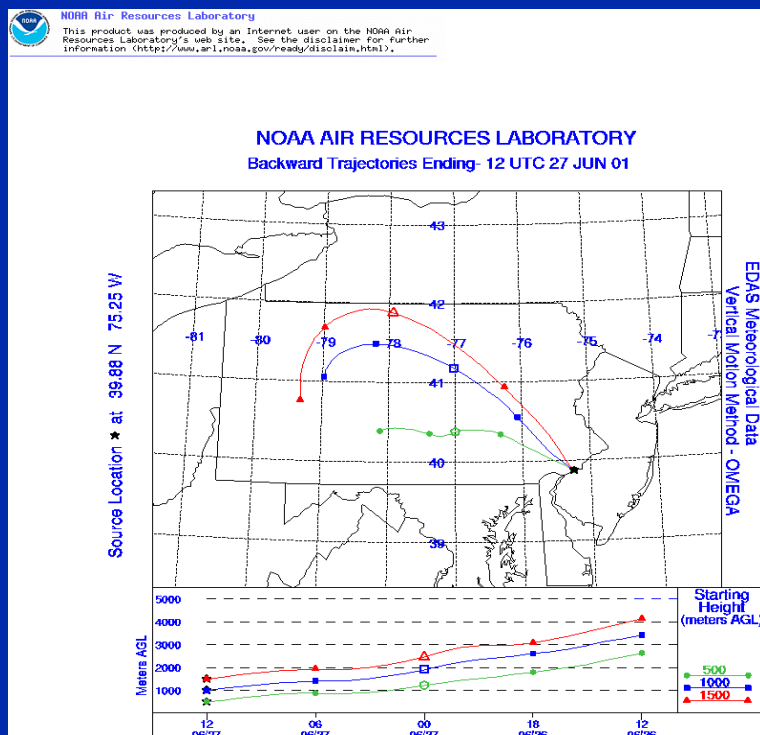
**Peak 8-hr O_3
AQI Color Codes**



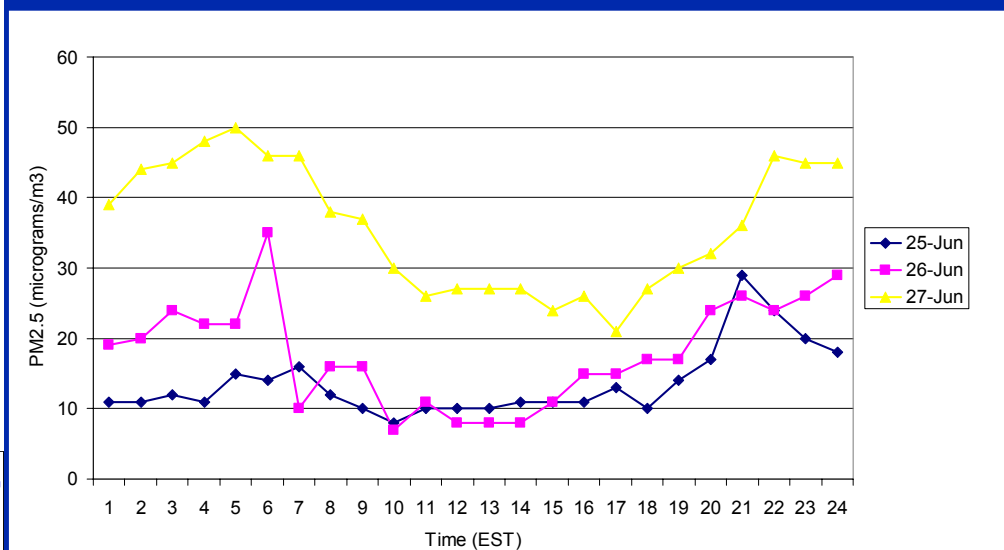
$PM_{2.5}$ June 27, 2001

June 27: Code Red O₃, PM_{2.5} Still Moderate (2 of 2)

Increase in PM_{2.5} was driven by increasing moisture and change in back trajectories.



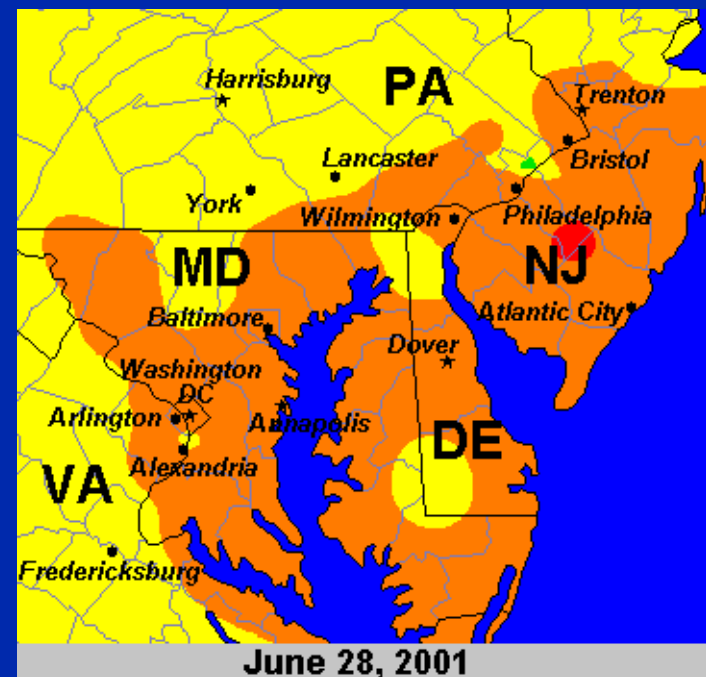
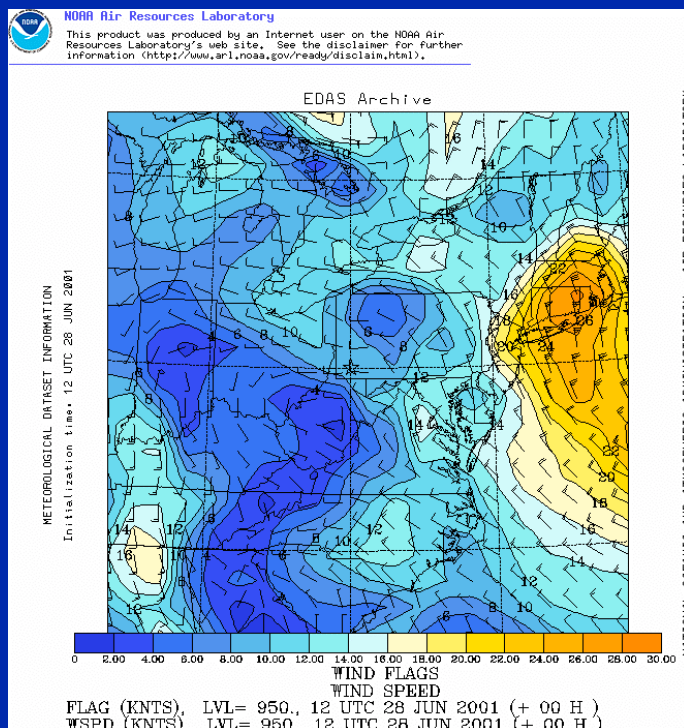
**HYSPLIT back trajectories
1200 UTC, June 27, 2001**



**Camden, NJ
PM_{2.5} (TEOM)
June 25-27, 2001**

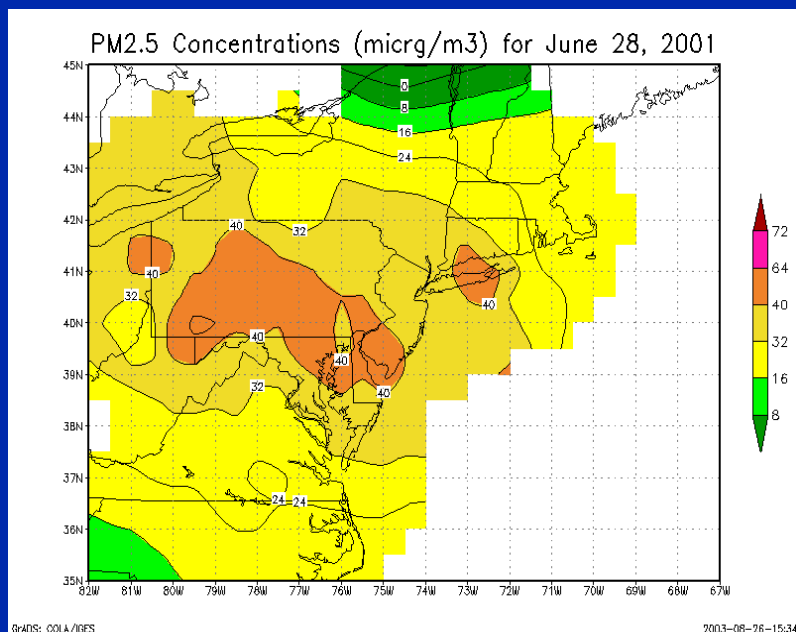
June 28: O₃ Fell, PM_{2.5} Rose

A weak short-wave disturbance crossed New England. A burst of high winds ventilated the mid-Atlantic with the highest concentrations pushed well east of I-95. Peak 1-hr concentrations decreased by ~20 ppbv.

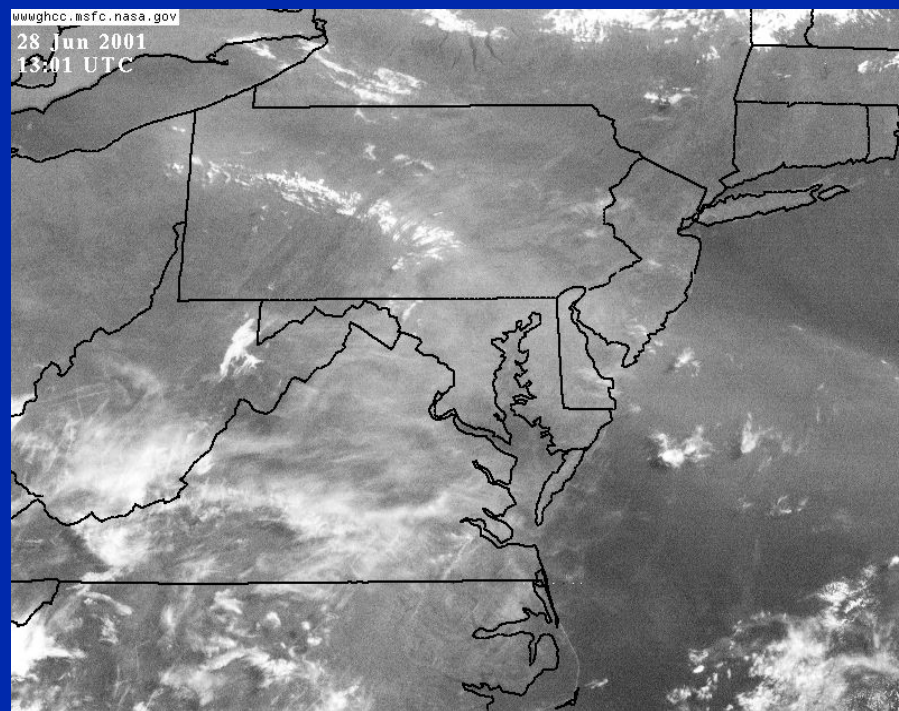


June 28: PM_{2.5} Concentrations Reached Code Orange

PM_{2.5} concentrations reached Code Orange and ranged over a wide area. Enhanced visible image shows the extent of the haze.



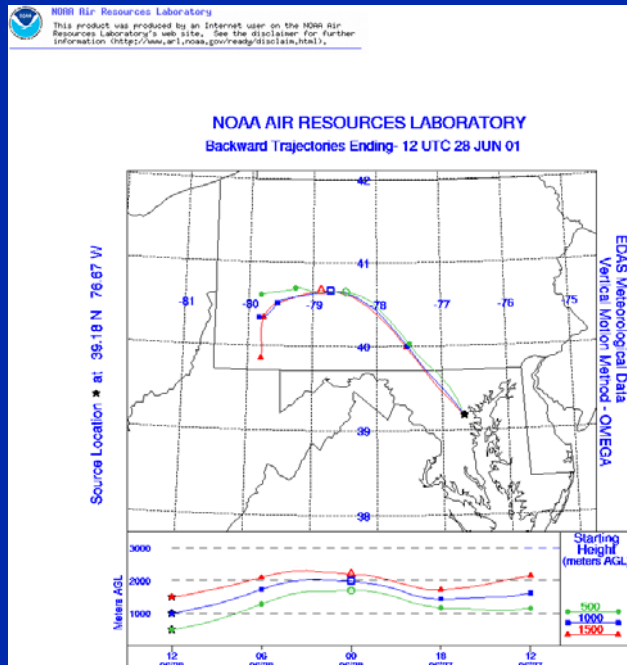
PM_{2.5} June 28, 2001



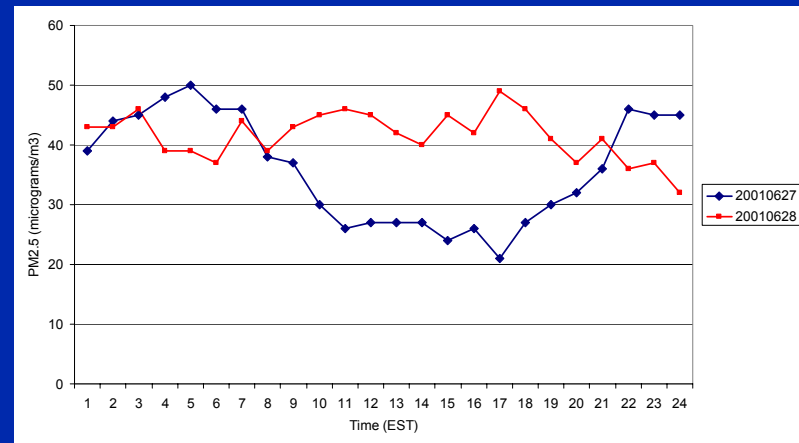
**Enhanced GOES Visible Image
1300 UTC, June 28, 2001**

June 28: What Drove Rise in PM_{2.5}?

The shift from stagnation to northwesterly transport pushed Code Orange-level PM_{2.5} into the region. The change in diurnal pattern (lower right) shows how afternoon mixing mixed down this PM_{2.5}-laden air.



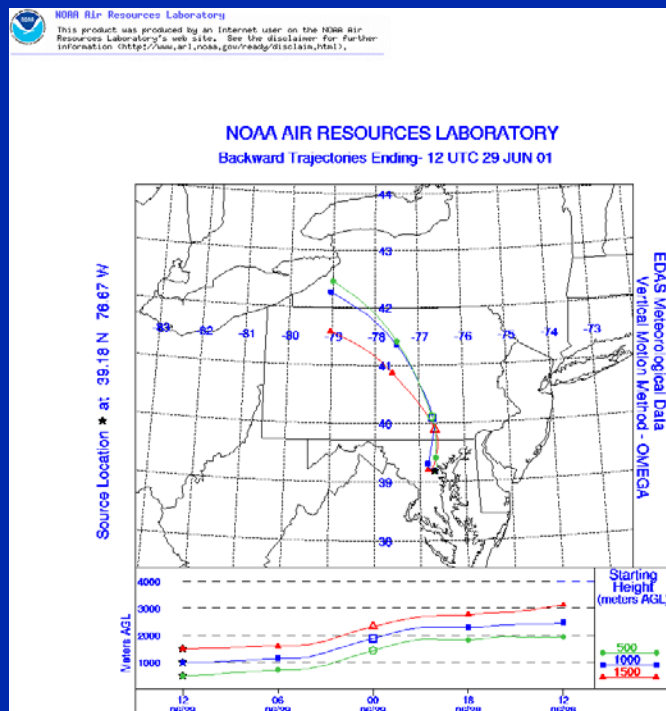
**HYSPLIT back trajectory
1200 UTC, June 28, 2001**



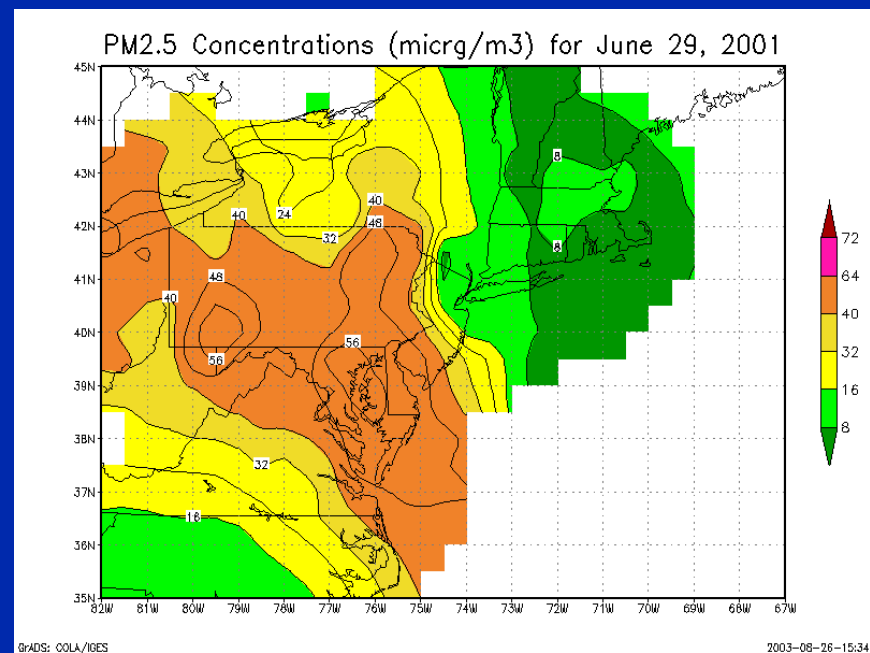
**Camden, NJ
PM_{2.5} (TEOM)
June 27-28, 2001**

June 29: PM_{2.5} Concentrations Peaked Across the Region.

- Another large increase in PM_{2.5} concentrations with a widespread area near the Code Red threshold.
- Continued northwesterly transport, strong subsidence, and dew points of 70⁺F combine to increase PM_{2.5}.



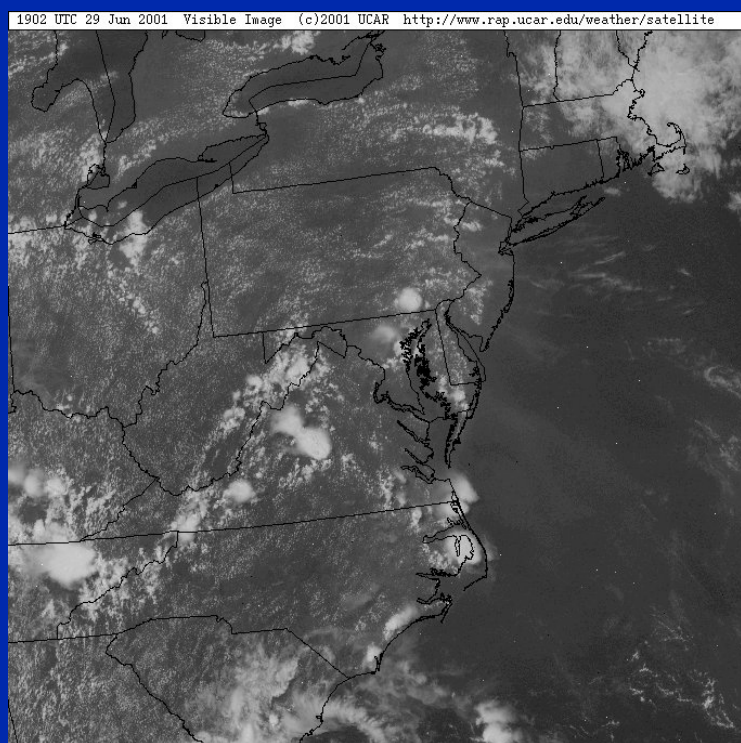
**HYSPLIT back trajectories
Valid 1200 UTC, June 29, 2001**



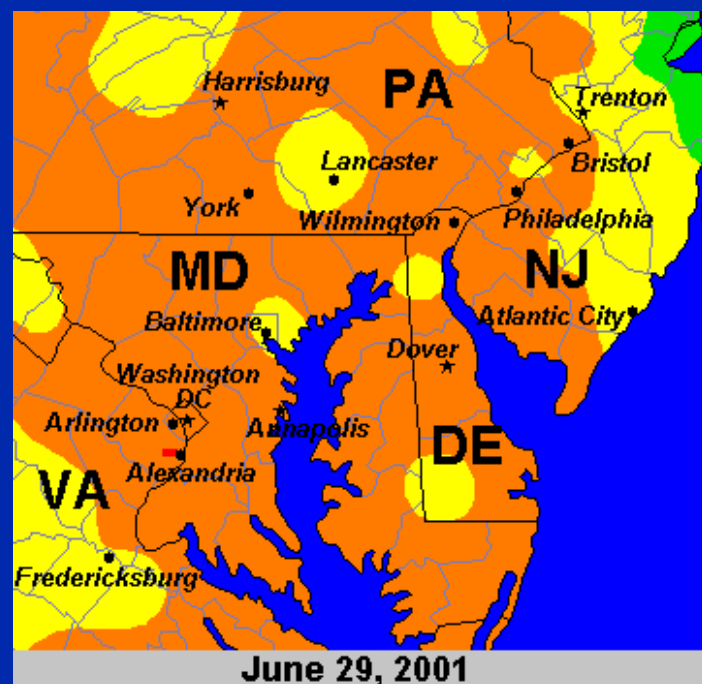
PM_{2.5} June 29, 2001

June 29: O₃ Concentrations Recovered

O₃ concentrations increased as surface winds became calm or variable. Convection was a bit more active.



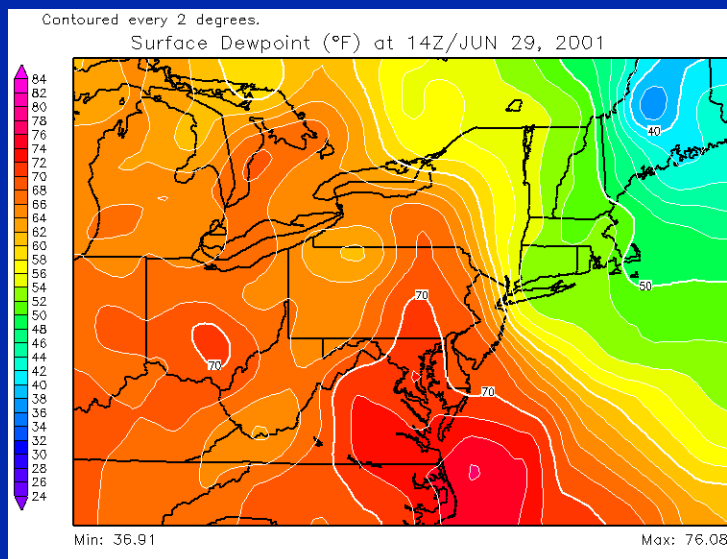
**GOES Visible Image
1900 UTC, June 29, 2001**



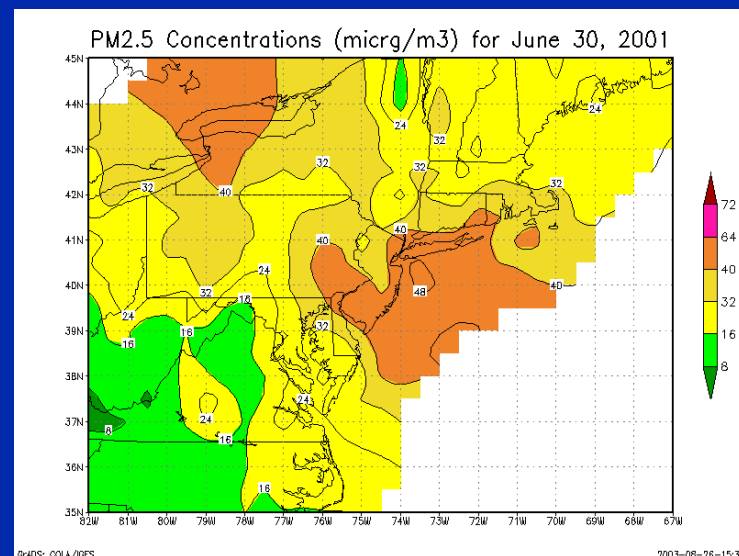
**Peak 8-hr O₃
AQI Color Codes**

June 30: Episode Slowly Wound Down

Extremely moist air mass (left panel) – good for particle-to-gas conversion – kept $\text{PM}_{2.5}$ high in parts of the region. Afternoon convection and a more tropical air mass cleaned out other areas.



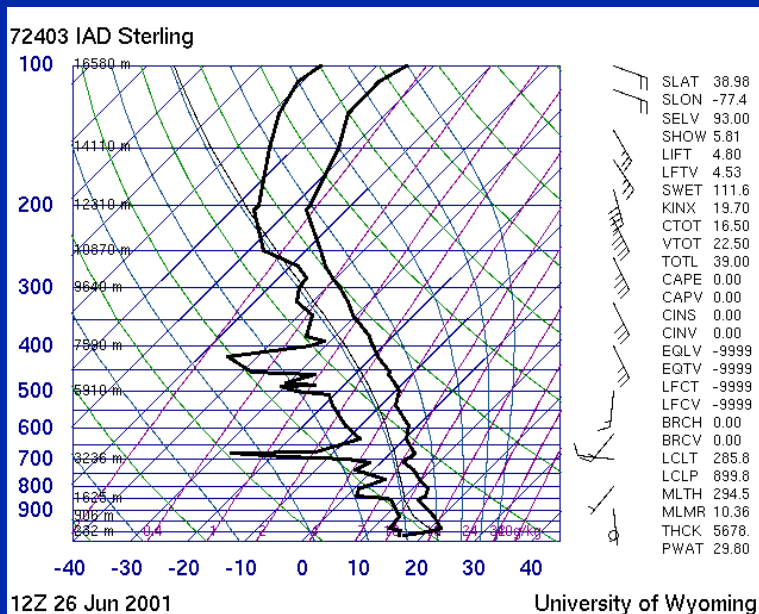
**Surface dew point temperature
1400 UTC, June 29, 2001**



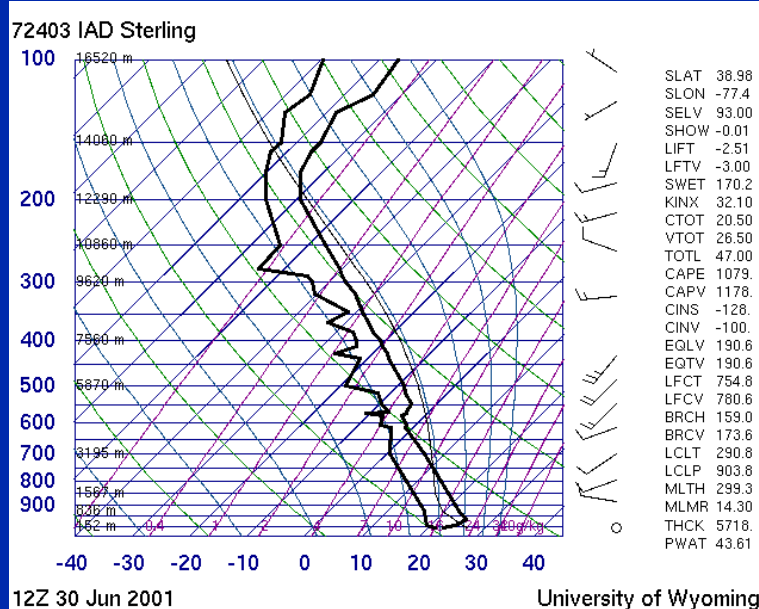
**$\text{PM}_{2.5}$ concentrations
June 30, 2001**

June 30: Unstable Air Mass

Although conditions were still warm (conducive to O_3) and moist (conducive to $PM_{2.5}$), the morning sounding on June 30 (right panel) was more unstable than earlier in the episode (left panel).



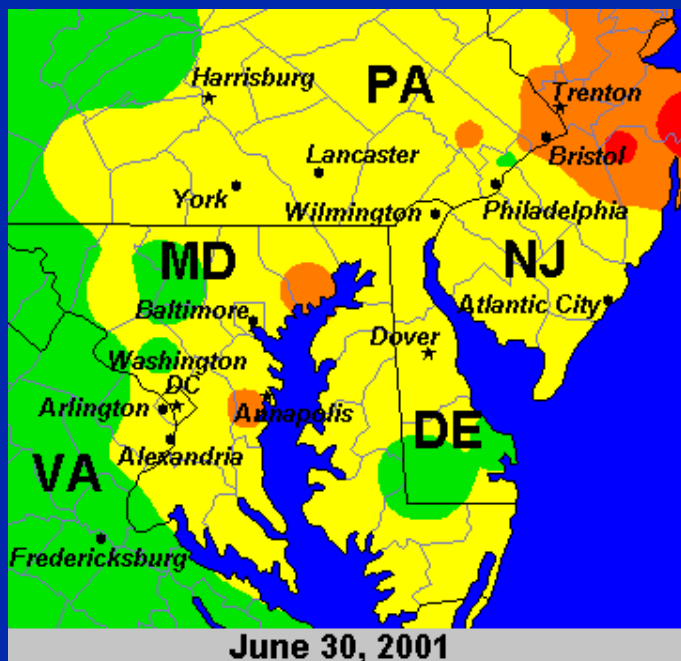
IAD radiosonde
1200 UTC, June 25, 2001



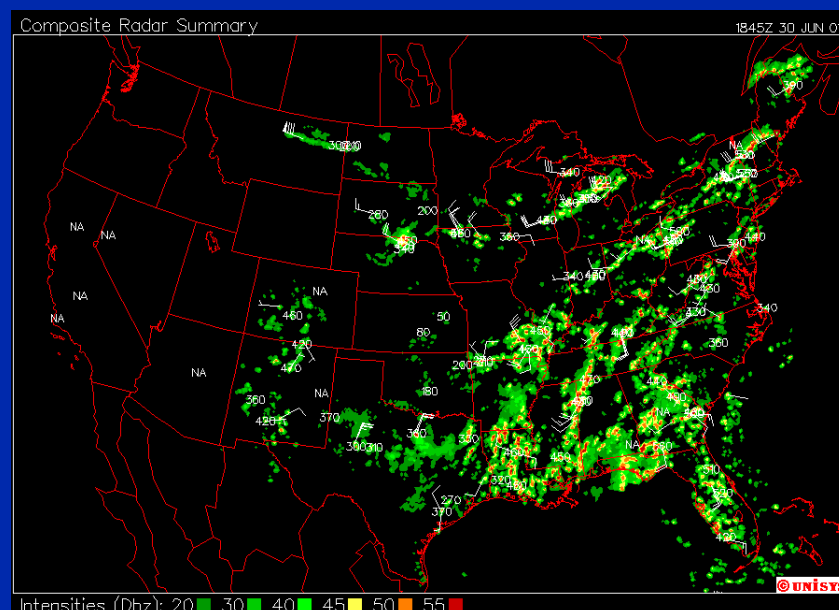
IAD radiosonde
1200 UTC, June 30, 2001

June 30: Convective Activity

Although only isolated thunderstorms occurred, deeper vertical mixing and a cleaner incoming air mass was sufficient to reduce both pollutants.



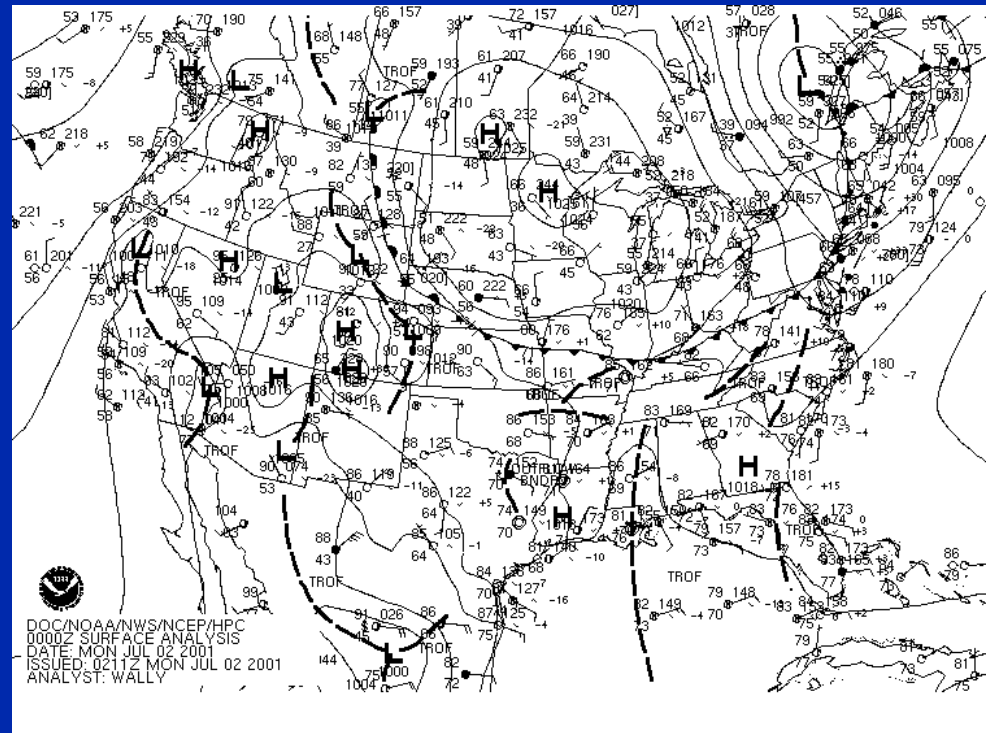
**Peak 8-hr O₃
AQI Color Codes**



**Composite radar summary
1845 UTC June 30, 2001**

July 1: Episode Ended

A cold front finally crossed the region during the day on July 1, bringing the episode to an end.



**NCEP Surface Analysis
Valid 0000 UTC, July 2, 2001**

Conclusions (1 of 2)

- Although $\text{PM}_{2.5}$ and O_3 share some sources and processes, enhanced concentrations need not occur in concert.
- Stagnation can lead to high $\text{PM}_{2.5}$, particularly in winter, but not in all summer cases. Low dew points are an indicator of lower $\text{PM}_{2.5}$.
- Knowledge of the characteristics of the residual layer is critical.

Conclusions (2 of 2)

- Summer season convection is often an afternoon phenomenon. As a result, it affects peak O_3 much more strongly than 24-hr average $PM_{2.5}$.
- Pollution episodes can end even in advance of a frontal boundary depending on the air mass advected ahead of the front.